

SCIENCE FOR CERAMICS PRODUCTION

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METHOD OF CALCULATING THE COMPOSITION OF CERAMIC PASTE BASED ON ACID LOAMS WITH SEMIACID CLAY ADDITIVE

E. N. Prudkov¹ and E. S. Lipatova¹Translated from *Steklo i Keramika*, No. 1, pp. 14–15, January, 2007.

A method is proposed for designing the charge composition of a two-component clay paste for production of rough wall ceramic based on acid loams and nontraditional semiacid clay additive with a high iron oxide content.

A small amount of semiacid low-melting or high-melting clays is added in practice to increase the strength of ceramic brick made from low-strength acid loams (USSR Inventor's Certificate No. 694474). Addition of semiacid clays improves the rheological properties of the molding paste and increases the strength and crack resistance in drying the intermediate products of plastic molding [1, 2].

Cheaper supplies of local semiacid clay raw materials have recently been sought as additives to low-strength acid loams.

Such clay raw materials or clay-containing rocks include pyritized clays containing more than 0.8%² FeS (in terms of SO₃), carbon-containing clays with a compact slate-like structure, clays with a large amount of iron oxides, etc. This clay raw material is unsuitable as the basic raw material for production of rough wall ceramics but is totally acceptable as a correcting additive to increase the strength of acid loams fired at 950–1000°C. In the last case, the two-component clay mass, including low-strength acid loams and nontraditional semiacid clay or clay-containing associated rock with a high Fe₂O₃ content, including pyrite, must satisfy the requirements of GOST 9169–75.

However, the studies showed that not all acid loams acquire high strength after firing when different semiacid clays containing a large amount of iron oxides or pyrite are added.

It has been theoretically and experimentally established that an increase in the strength on addition of these semiacid clays to acid loams is observed for a Fe₂O₃ content in the acid loams of less than 4.5% and a (Al₂O₃ + TiO₂) : Fe₂O₃ ratio greater than 2.7. It should be noted that a long time is

required for conducting the experimental study for selecting the charge composition of the two-component paste based on low-strength acid loams with $R_{\text{com}} = 25 - 30$ MPa and higher (firing at 950–1000°C). To reduce the duration of experimental development of the charge composition of two-component ceramic paste, we developed a method for this projection (prediction) by calculation.

Several compositions of ceramic molding pastes from acid loams from different deposits in the Tula, Orel, Smolensk, and Kaluga regions with addition of semiacid clay containing a large amount of Fe₂O₃ (more than 15%) were first prepared by the experimental method. The amount of such semiacid clay as additive varied from 5 to 35% (maximum possible amount). The appearance of cracks during natural drying at 20 ± 2°C and signs of swelling during firing were the criterion of the limit.

Experimental lots of samples measuring 50 × 50 × 50 mm with a 20% molding moisture content were prepared by the method in [3]. All samples were fired in a muffle furnace at the maximum temperature of 950°C with holding for 1 h. A control lot of samples consisting of acid loams (100%) prepared in the same process conditions and parameters had a compressive strength of 14 MPa on average.

One lot of samples with the maximum strength attained of 38.2 MPa, consisting of acid loams with a less than 4.5% Fe₂O₃ content and (Al₂O₃ + TiO₂) : Fe₂O₃ ratio greater than 2.7 with 20% semiacid clay added were separated from many experimental lots. The composition of this lot of samples was used as the standard. It should be noted that the standard composition remained acid, but close to semiacid, in chemical composition, more accurately, with respect to the Al₂O₃ content in calcined substance. The two-component paste of

¹ Tula State University, Tula, Russia.

² Here and below: mass content.

unsintered acid clay with addition of semiacid clay was converted into medium-sintered mixed clay raw material.

The experimentally found chemical composition of the raw material was the basis for designing and calculating the two-component clay paste including low-strength acid loams and semiacid clay with a high iron oxide content (including clay-containing associated rocks).

The method of design and calculation includes a number of steps.

1. Equations with two unknowns of the X and Y type are formulated and solved:

$$XA + YB = C; \quad (1)$$

$$XD + YE = F, \quad (2)$$

where X and Y are the quantity of acid loams and semiacid clay in the total clay paste, kg; A and B are the fraction of SiO_2 in the acid loams and semiacid clay, % $\text{SiO}_2/100$; C and F are the mass content of SiO_2 and Al_2O_3 in the standard ceramic composition; D and E are the fraction of Al_2O_3 in the acid loams and semiacid clay, % $\text{Al}_2\text{O}_3/100$.

After determining the consumption of dry acid loams X and semiacid clay Y with consideration of calcination loss, the total mass in kilograms is calculated:

$$M_{\text{dry}} = X + Y.$$

Then the values of X and Y are converted to wt.%.

For example, in one calculation we obtained; consumption of acid loams, 79 kg (X), consumption of semiacid clay, 28 kg (Y); total of 107 kg.

The content of each oxide (except for SiO_2 and Al_2O_3) added to the paste with the semiacid clay is determined similarly with consideration of the calcination loss.

As a consequence, for designing the composition of a wall ceramic with a minimum strength of 38.2 MPa, it is necessary to use: 73.8% acid loams and 26.2% semiacid clay.

The reliability of the calculation was confirmed experimentally. As a result, an experimental lot of samples with a compressive strength of 39.1 MPa was obtained, which is slightly higher than the strength of the standard samples for acid loam strength of 14.5 MPa.

2. The amount of other oxides (except for SiO_2 and Al_2O_3) added to the clay paste composition (with consideration of calcination loss) initially with the loam and then the semiacid clay is determined.

For example, Fe_2O_3 is added to the dry paste with the loam: $4.1 \times 0.738 = 3.026\%$ (4.1 is the mass content of Fe_2O_3 in the dry loams, %) and so on for each oxide, including for calcination loss.

3. The total amount of oxides added to the paste with the acid loam and semiacid clay, including the calcination loss (except for SiO_2 and Al_2O_3) is summed. The amount of SiO_2

and Al_2O_3 was previously planned in calculating Eqs. (1) and (2).

The complete chemical composition of the planned dry ceramic paste is determined in this way.

4. The chemical composition of the dry ceramic paste in calcined substance is recalculated and the chemical composition of the planned ceramic is determined without consideration of calcination loss.

5. A comparative quantitative analysis of the standard chemical composition of the ceramic and the planned composition is conducted with respect to each oxide (except for SiO_2 and Al_2O_3) and a conclusion is drawn, which consists of the following:

if the difference between each oxide of the desired ceramics and the reference composition of Fe_2O_3 , $\text{CaO} + \text{MgO}$, $\text{K}_2\text{O} + \text{Na}_2\text{O}$ and TiO_2 equals 1 – 1.5% then the semiacid clay plays the role of a corrective additive that increases the acid adobe strength, thus a desired mass in practice provides the compression strength of ceramics no less than the strength of the reference composition (38.2 MPa at a firing temperature of 950°C);

if the difference is from more than 1.5 to 2.5%, then the compressive strength will be from 20 to 30 MPa if the compressive strength of the acid loams used is 9 – 17 MPa;

if the difference is greater than 2.5 – 3%, then the semiacid clay (or clay-containing associated rock) does not have a positive effect on the increase in the strength or the effect will be insignificant; associated semiacid clays or clay-containing rocks with calcination loss greater than 25% are not recommended as a correcting additive.

Our method of predicting the charge composition of two-component clay paste for production of rough wall ceramics based on low-strength acid loams and nontraditional semiacid clay additives containing a large amount of Fe_2O_3 thus allows:

reducing the duration of the experimental study to select a ceramic paste composition and computerizing the calculation process;

conducting a theoretical study of many deposits and clay-containing rock banks for their suitability in ceramic pastes for rough wall ceramics, which is also pressing for environmental protection.

REFERENCES

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